DRAFT TECHNICAL REPORT:

The following text is a working technical document.   This draft technical report an be referred to when making out the matrix for Management Issues within the Pocono Watershed.

Please concentrate on TEXT, and the delivery of information. Tables, Maps, Graphs are not yet numbered. The Final Draft will contain all sequential numbering labels. Also, due to the limitations of the WORD program, random page breaks occur, splits in text, etc. These will be corrected in the final copy.

B. Aquatic Ecology

Pocono Creek's watershed has all of the necessary ingredients to develop an exceptionally high richness, diversity, abundance, and balance of aquatic life. As indicated by all aquatic life indicators surveyed to date, such as fish, benthic macroinvertebrates, and habitat, the Pocono Creek watershed possesses nearly optimal physical and chemical conditions, and is resilient to man's activities. Continued resilience and high quality depends upon some critical factors such as abundance of water, minimally impacted headwaters, large tracts of undeveloped space, and the geological structure of the area. All of these features combined minimize impacts of existing development. The Pennsylvania Department of Environmental Protection (PADEP) classifies most streams in the watershed as high quality cold-water fisheries (HQ-CWF). Portions of the watershed are classified as exceptional value (EV) streams. HQ and EV status signifies that the Pocono is suitable for Pennsylvania's anti-degradation water quality protection strategies for waters that exceed state standards, and that possess exceptionally high water resource values. The Pennsylvania Fish and Boat Commission (PFBC) classifies the Pocono Creek as a Class A wild trout stream, finding significant populations of wild brook trout and wild brown trout. Habitat scores consistently range in the optimal to sub-optimal range.

Table ___. PADEP Chapter 93 Use Designations for the Pocono Creek Watershed

1-Delaware River		
2-Brodhead Creek		
3-McMichael Creek (above Pocono Cr.)	Basin, T434 to Pocono Creek	HQ-CWF
4-Pocono Creek	Main Stem	HQ-CWF
5-Unnamed Tributaries to Pocono Creek	Basins	HQ-CWF
5-Dry Sawmill Run	Basin	HQ-CWF
5-Sand Spring Run	Basin	EV
5-Wolf Swamp Run	Basin	EV
5-Scot Run	Basin	HQ-CWF
5-Bulgers Run	Basin	HQ-CWF
5-Cranberry Creek	Basin	HQ-CWF
5-Reeders Run	Basin	HQ-CWF
5-Wigwam Run	Basin	HQ-CWF
5-Flaglers Run	Basin	HQ-CWF
5-Big Meadow Run	Basin	HQ-CWF
3-McMichael Creek (below Pocono Cr.)	Basin, Pocono Creek to Mouth	TSF

(No exceptions are listed to the above water uses protected.)

EV = Exceptional Value Waters. Special Protection. A stream or watershed which constitutes an outstanding national, State, regional or local resource, such as waters of national, State, or county parks or forests, or waters which are used as a source of unfiltered potable water supply, or waters of wildlife refuges or State game lands, or waters which have been characterized by the Fish Commission as "Wilderness Trout Streams," and other waters of substantial recreational or ecological significance.

HQ = High Quality Waters. Special Protection. A stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection.

CWF = Cold Water Fishes. Maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.

TSF = Trout Stocking. Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

In addition to abundant trout streams, the Pocono Creek watershed possesses other ecologically valuable attributes. As a transition area between ecoregions (from the Appalachian Plateau into the Ridge and Valley ecoregion), the watershed contains more diversity of life and life zones than other watersheds of similar size in Eastern Pennsylvania. Atop the plateau, low gradient and low pH tannic streams drain the landscape of bogs, swamps, and pine forest. Cranberry Bog is a protected area in the east-central portion of the watershed. It is the southernmost alpine bog in the United States. From this and other wetland and water-rich areas, water feeds down, off the Pocono Plateau, through steep V-notched valleys in boulder and cobble-dominated river channels to a fairly wide U-shaped valley in the lower third of the watershed. The entire watershed may be viewed as a glacial-till bowl, full of water.

However favorable the environment may be for growth, development, and reproduction of aquatic life, many negative impacts have been observed in localized areas. The natural resilience of the watershed is being tested by development, transportation, and maintenance practices. The drought of 1999 reduced abundance and biomass of brown trout. Contributing factors were low water levels, lack of trout habitat and refuge, and elevated water temperatures. Storm water runoff from parking lots and roads caused habitat damage to a section of Pocono Creek near Flagler Run (under Stroud Mall). Numerous instances of localized stream modifications such as roads, bridges, culverts, channeled areas, floodplain development, and riparian vegetation removal caused scouring or sedimentation damage to many streams of the watershed. Stream bank erosion and channel instability are signs that the natural equilibrium of the creeks has been disrupted, but not yet to a great degree except in local areas. Evidence indicates that the Pocono Creek watershed is a high-quality resource on the edge of a fall, and that same evidence may reveal the thresholds at which impairment occurs.

In the following sections addressing aquatic ecology, results of recent fishery and benthic macroinvertebrate surveys and assessments are presented. Both fish and macroinvertebrates will serve as numerical indicators, or targets, used to measure the degree of success of various management strategies employed in pursuit of water resource goals established by residents, towns, and agencies of the Pocono Creek watershed. Three agencies have recently surveyed the fish and macroinvertebrates of Pocono Creek: the Pennsylvania Fish and Boat Commission surveyed fish in 1998 and 1999; the Pennsylvania Department of Environmental Protection's Unassessed Waters project completed surveys of the Pocono and its tributaries in 1998; and the

Monroe County Planning Commission has continued its benthic macroinvertebrate monitoring program every year since implementation of its ecoregional benthic scoring system in 1993.

Macroinvertebrates

Benthic macroinvertebrates, or bottom-dwelling insects and other aquatic organisms, have historically served as indicators and direct measures of water quality. They are sensitive to pollution, easily and cheaply collected and identified, and long-lived. Spending most or all of their lives on stream-bottoms, they are commonly used as integrators of all water quality conditions over a year's period.

The 1993 Monroe County Surface Water Study marked a significant change in the way that the County looks at its surface water. This study began the process of integrating the US Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols or RBPs (Barbour et al. 1999). The RBPs examine water quality as it relates to the macroinvertebrate community and their habitat. This allows for examination and comparison of existing versus the potential quality of the stream. This year was the first year in which the county worked side by side with the EPA.

The 1994 and 1995 studies continued integrating EPA's Rapid Bioassessment Protocols. During these two years many decisions were made. In order to determine which streams could be compared as similar, the EPA's ecoregion information (Omernik 1987; see Figure ___ for ecoregional map of the Pocono watershed) was chosen instead of watershed boundaries. Due to the large size of the ecoregions, the County decided to use the sub-ecoregion information. The use of sub-ecoregions allowed the County to create reference conditions instead of determining reference sites. When a reference site is used, all other sampling stations on that stream must be compared to that location. If that location is disrupted, then all analyses are biased, invalidating the data until a different reference site is found. The reference condition incorporates numerous reference sites from various streams with a similar makeup to create a scoring scheme, which is used to rank all sampling stations from that sub-ecoregion. Such a system has proven to be very dependable, and directly relevant to local water quality conditions.

FIGURE ___: Map of Pocono Creek Sub-Ecoregions

It was determined in 1994-1995 that macroinvertebrate assemblages from larger streams (draining more than 10 mi^2) differed from smaller streams. Sub-ecoregion streams were thus broken into two smaller categories: streams with a drainage basin of less than 10 square miles; and those with a drainage basin of greater than 10 square miles. The Northern Sandstone Ridges sub-ecoregion is comprised solely of streams that are less than 10 square miles in drainage area, so only the first scoring scheme applies to this sub-ecoregion. Once the proper ecoregion and size of the drainage area of a site is determined, then proper metrics can be applied. Metrics are simply numerical values assigned to ecological properties of a population. There are hundreds of possible metrics, but all can be assigned to groups measuring richness, diversity, balance, pollution tolerance level, or feeding habits of benthic invertebrates or fish. In 1995, the initial scoring schemes were created and covered approximately two thirds of the streams in the County. The scoring scheme is composed of various metrics, statistically defined to be the most sensitive to water pollution. This creates a conservative and direct measure of the biological "health" of the stream.

From 1996 through 1999, the County continued the work of establishing reference conditions. The County examined those areas that remained with no scoring scheme, which was comprised of two sub-ecoregions. The first, Northern Shale Valleys and Slopes, could be broken out into drainage basins of greater than and less than 10 square miles. The second sub-ecoregion, Northern Sandstone Ridges, contains only streams with a drainage area of less than 10 square miles. In the 1998 study the final scoring scheme (Northern Sandstone Ridges) was completed. It should be noted that this scoring scheme was developed using a limited number of sites and will be refined in the future. Also during the 1998 study, the County began research on the remediation of impacts and restoration of any impaired sites found through use of the macroinvertebrate studies. During the 1999 study, the County began to explore integrating the data from the Water Quality Studies into the GIS system. The 2000 study followed the same format as the previous years, though numerous sites were added in the Pocono Creek watershed.

HABITAT ANALYSIS (performed by Monroe County Planning Commission and PADEP)

Both the quality and quantity of available habitat affects the macroinvertebrate community. A healthy biological community not only requires good water quality, but also a supporting habitat. Sampling areas where habitats are similar minimize variability attributed to habitat bias. This way, impacts to the biological community can be attributed to water quality. When sampling station habitats are not comparable, it is important to consider the differences when interpreting the bio-survey results.

Since 1993, each sampling station's habitat has been rated. There are two types of rating systems. One is for a riffle/run prevalent stream, like most of the streams in Monroe County. The other is for glide/pool prevalence. Only a few stations in this study were rated using the latter system. The rating system incorporates three categories for a total of twelve parameters. The following is an explanation of the habitat parameters:

Habitat Parameter Descriptions

<u>RIFFLE/RUN COMMUNITY</u>

<u>Substrate/Instream Cover</u>

1. **Instream Cover:**
   This is a measure of quantity and variety of natural structures in the stream that will provide a habitat for fish. This would include fallen trees, logs, and branches, undercut banks and large rocks. A wide variety of substrate will support greater diversity.

2. **Substrate for Benthic Macroinvertebrates:**
   This measures the amount of hard substrate available for insects and snail habitat. Many insect larvae attach themselves to submerged substrate. Areas with rocky bottoms are critical for maintaining a healthy variety of insects.

3. **Embeddedness:**
   This refers to the degree to which rocks are covered or sunken into the silt, sand or mud. As substrate becomes embedded in the stream bottom, the amount of surface space for insects to attach themselves decreases. As substrate becomes embedded, the quantity and quality of the macroinvertebrate community will decrease.

4. **Velocity/Depth Regime:**

There are four basic velocity/depth combinations:

1. Slow-deep; 2. Slow-shallow; 3. Fast-deep; and 4. Fast-shallow.

General guidelines are as follows: 0.5m separates deep from shallow: 0.3m/s separates fast from slow. Streams that contain all four regimes are considered optimal.

Channel Morphology (form and structure)

5. **Channel Alteration:**

This parameter is a measure of changes to the shape of the stream channel. Streams that run through agricultural or urban areas may have been altered many times. When streams have been changed in any way (i.e., straightened, deepened, diverted, concrete channelized, artificial embankments or stabilization, dams or bridges) it can affect the macroinvertebrate community. Streams that have been altered have fewer natural habitats for fish, macroinvertebrates and plants.

6. **Sediment Deposition:**

This parameter measures the sediment, which has accumulated on the stream bottom as a result of deposition. Deposition occurs as a result of large-scale movement of sediment caused by watershed erosion. This deposition may cause the formation of islands or point bars in the stream, which decreases the available habitat for macroinvertebrates.

7. **Frequency of Riffles:**

This parameter assumes that a stream with riffles or bends provides more diverse habitat than any straight or uniform depth stream. The ratio is calculated by dividing the average distance between riffles or bends by the average depth. The smaller ratio is an indicator of good habitat.

8. **Channel Flow Status:**

This is a measure of the degree to which the channel is filled with water. When the water reaches the base of both banks and a minimal amount of channel substrate is exposed, optimal conditions exist.

Riparian and Bank Structures

9. **Condition of Banks:**

This parameter addresses stream bank erosion (or potential for erosion). Steep banks are generally more subject to erosion and failure. Signs of erosion include crumbling and unvegetated banks and exposed tree roots and soil.

10. **Bank Vegetative Protection:**

This measures the amount of stream bank, which is covered by vegetation. Plant root systems on stream banks help to hold the soil in place. This reduces the stream bank erosion. This parameter also provides information such as stream shading and nutrient uptake. Banks with full natural plant growth are better for macroinvertebrates and fish.

11. **Grazing Disruptive Pressure:**

This parameter measures the impact to the riparian zone due to livestock grazing or human activities such as urbanization, golf courses and residential development.

12. **Riparian Zone Width:**

This is a measure of the width of the natural vegetation from the edge of the stream bank. This zone serves as a buffer to pollutants entering the stream from run off and erosion. It also provides nutrients to the stream. An undisturbed riparian zone is reflective of a healthy stream, while a narrow riparian zone is not as healthy for a stream. Roads, parking lots, fields, lawns, rocks, bare soil or buildings near a stream bank have a detrimental effect on habitat.

GLIDE/POOL COMMUNITY

Substrate/Instream Cover

1. **Instream cover:**

This is a measure of quantity and variety of natural structures of the stream that provides a habitat for fish. This would include fallen trees, logs and branches, undercut banks, and large rocks. A wide variety of substrate will support greater diversity.

2. **Substrate for Macroinvertebrates:**

The substrate in muddy bottom streams consists mostly of submerged logs, snags and aquatic vegetation.

3. **Pool Substrate Composition:**

This is an evaluation of the type and condition of bottom substrates found in pools. Firm sediment types such as gravel and sand as well as rooted aquatic plants support a wider variety of organisms. A pool substrate dominated by mud or bedrock will not support a diverse community. A variety of substrate is needed for diversity.

4. **Pool Variability:**

This parameter rates the overall mixture of pool types found in the streams. The four basic types of pools are: (1) Large-shallow; (2) Large-deep; (3) Small-shallow; and (4) Small-deep. General guidelines are as follows: greater than one half the cross-section to separate large from small and one meter separating shallow and deep.

Channel Morphology (form and structure)

5. **Channel Alteration:**

This parameter is a measure of changes to the shape of the stream channel. Streams that run through agricultural or urban areas may have been altered many times. When streams have been changed in any way (i.e., straightened, deepened, diverted, concrete channelized, artificial embankments or stabilization, dams or bridges) it can affect the macroinvertebrate community. Streams that have been altered have fewer natural habitats for fish, macroinvertebrates and plants.

6. **Sediment Deposition:**

This parameter measures the sediment, which has accumulated on the bottom as a result of deposition. Deposition occurs as a result of large-scale movement of sediment caused by watershed erosion. This deposition may cause the formation of instream islands or point bars, which decreases the available habitat for macroinvertebrates.

7. **Channel Sinuosity:**

This is an evaluation of the frequency of bends in a stream. Streams that meander provide a variety of habitat for macroinvertebrates. Straight stream segments provide for monotonous habitats and are prone to flooding. The bends in the stream also protect the banks from erosion.

8. **Channel Flow Status:**

This is a determination of the percent of the channel that is filled with water. The flow status changes as the channel enlarges or as flow is decreased as a result of dams or obstructions, diversions for irrigation, or drought. When water does not cover as much of the streambed the available habitat is decreased.

Riparian and Bank Structure (Refer to riffle/run definition)

9. **Condition of Bank**
10. **Bank Vegetative Protection**
11. **Grazing Disruptive Pressure**
12. **Riparian Vegetative Zone Width**

Each sampling station's habitat is rated using the previously discussed parameters. Each parameter is scored from 0-20 as follows:

Score	Category
0-5	Poor
6-10	Marginal
11-15	Suboptimal
16-20	Optimal

Each parameter is summed for a final habitat score for a particular station.

Score	Category
0-60	Poor
72-120	Marginal
132-180	Suboptimal
192-240	Optimal

Habitat is a major factor in determining the potential of the aquatic community. A marginal or poor habitat is not expected to support the quantity and quality of macroinvertebrates that an optimal habitat will.

STREAM BOTTOM

Substrate (the base on which an organism lives, in this case the stream bottom) is one of the most important factors controlling the community of macroinvertebrates. Over a period of time, the natural substrate may be greatly altered by the discharge of organic matter. The location and expanse of various substrate types may change due to normal variations in hydraulic factors such as volume of flow. Changes in the nature and properties of the substrate may provide clues on the quality and quantity of the pollutants. Where the pollutant has a direct effect on the characteristic of the substrate, the effects of the changes in water quality may be inseparable from the effects of changes in the substrate.

<u>Substrate types</u>

<u>Inorganic Components:</u>
Bedrock is solid rock.
Boulders are 256 mm (10 inches) or more in diameter.
Cobble is between 64 and 256 mm (2.5-10 inches) in diameter.
Gravel is between 2 and 64 mm (1.5-2.5 inches) in diameter.
Sand is between 0.06 and 2.0 mm in diameter; gritty texture.
Silt is 0.004 mm in diameter; smooth texture.

<u>Organic Components</u>
Detritus is accumulated wood, sticks and other non-decayed coarse plant matter.
Muck is black, finely divided organic matter, not completely decomposed.

The substrate composition for the sampling sites in this study was visually determined in the field.

BENTHIC MACROINVERTEBRATES

In addition to the standard chemical and physical parameters used as water quality indicators, samples of benthic macroinvertebrates were also collected whenever possible. Aquatic macroinvertebrates are animals that are large enough to be seen by the unaided eye and live at least part of their life cycles within or upon available substrates in a body of water or water transport system. These include insects such as mayflies, annelids, mollusks, flatworms, roundworms, and crustaceans. The samples collected allow for a detailed analysis of the aquatic community. A brief explanation of these factors is offered to enable the reader to understand the importance of measuring the relative stability of the aquatic community.

The sampling technique is a standard kick sample format using a 1meter x 1meter seine. Normally one sample (one square meter of substrate) is taken from a riffle in the stream and one sample (one square meter of substrate) is taken from a run. The entire sample is taken to the Monroe County Conservation District office where it is sub-sampled. A sub-sample of 100 organisms is desired for a valid analysis.

The following are the metrics used for the macroinvertebrate analysis. Metrics are the various counts, indexes, and ratios computed from the results of the sub-samples as described above. Different metrics convey different types of information about the macroinvertebrate community. For example, taxa richness is an index of diversity and the Hilsenhoff Biotic Index measures pollution tolerance. By using a set of metrics that measures multiple aspects of the macroinvertebrate community, a complete picture of a community can be obtained.

<u>Total Individuals</u> is the actual number of macroinvertebrates collected.

<u>Total Taxa</u> (Species richness) is a measure of the variety of taxa (total number of species) present. This generally increases with increasing water quality or habitat. In some situations, organic enrichment may also result in an increase in the number of taxa.

<u>Percent Contribution of Dominant Taxa</u> gives an indication of the balance in the community. A community dominated by relatively few species would indicate environmental stress. An even distribution of all taxa (preferably sensitive species) is more desirable.

<u>Percent Noninsects</u> gives an indication of the balance in the community. Noninsects are generally tolerant species. A community dominated by noninsects would be an indication of environmental stress. An even distribution of all taxa (preferably sensitive species) is more desirable.

<u>Modified Hilsenhoff Biotic Index</u> (HBI) is a ranking based on pollution tolerance to organic sources values. These values range from 0-10 increasing as water quality decreases. The Biotic Index is an average of tolerance values for all individuals collected from a site.

The following demonstrates the range for Biotic Index:

0.00-3.75	Excellent
3.76-4.25	Very Good
4.26-5.00	Good
5.01-5.75	Fair

5.76-6.50	Fairly Poor
6.51-7.25	Poor
7.26-10.0	Very Poor

EPT Index is a measure of the total number of distinct taxa within the orders of Ephemeroptera, Plecoptera and Trichoptera. This summarizes the taxa richness within the insect orders that are generally sensitive to pollution. The EPT Index generally increases with increasing water quality.

Percent Intolerant Taxa gives an indication of the balance in the community. Intolerant organisms are usually not found associated with organic contaminants and are generally intolerant of even moderate reductions in dissolved oxygen. Intolerant organisms are indicators of clean water only.

The Ratio of Shredders to the Total Number of Insects uses the relative abundance of shredders as an indication of the dominant food or energy source in a small watershed. Shredders are insects that shred coarse particulate detritus for feeding. Shredders represent a distinct functional feeding group that is found predominantly in watersheds less than 10 square miles in size where the primary energy source in the stream is derived from leaf litter and similar detritus entering the watercourse. Shredders should become less abundant as the stream width increases and the canopy cover opens and photosynthesis becomes the primary energy source in the stream.

Scoring Schemes

Scoring schemes have been completed for the entire County. The EPA conducted the majority of the statistical analysis needed to determine the metrics that are used for the Pocono Plateau and Low Pocono sub-ecoregions. Most metrics were selected because of their ability to discriminate between impaired and candidate reference sites. The County completed the work for the remaining sub-ecoregions in the County, but without the help of the EPA this work would have been much more difficult.

A simple process was used to develop the reference conditions for the different stream classes. Within each stream class, minimally impaired reference sites were sampled. Descriptive statistics for each metric were calculated from a group of similar candidate reference sites. Only the candidate reference sites with optimal habitat and intact benthic macroinvertebrate communities were included in the reference condition. Test sites, or sites thought to be impaired, were not used in the development of reference conditions. Thresholds for optimal, slightly to moderately impaired and severely impaired categories were developed for each metric. The data from each metric was compiled and ranked. If a metric increases with impact (HBI for example), the 75th percentile of the reference condition is used as the threshold for the optimal category. The remaining range between that value and the maximum value obtainable for that metric was halved to provide two more ranges for scoring the slightly to moderately impaired and severely impaired categories. If the metric value decreases with impact (taxa richness for example), the 25th percentile of the reference condition is used as the threshold for the optimal category. The remaining range between that value and the minimum value was halved to provide two more ranges for scoring the slightly to moderately impaired and severely impaired categories. For some metrics, this may result in somewhat insensitive scoring. For percent non-insects, for example, the maximum possible is 100%. However, 25% was the maximum encountered in the severely impacted sites for the Pocono Plateau / Glide Pool sub-ecoregion. The scoring was adjusted to reflect the values of that metric generally encountered in impacted streams for this sub-ecoregion, in order to make the scoring for that metric more sensitive.

All candidate reference sites were scored using the scoring scheme for that stream classification. These scores were then ranked. The lower 25th percentile was used to define the lower range of the optimal category. The remaining range between that value and the minimum possible total score was bisected to define two more ranges for the slightly to moderately impaired and severely impaired categories for the total scores.

The County identified all organisms collected to the family level and all the calculations were performed using family level identifications. The family level of identification was chosen to make data sharing both easier and faster (both the EPA and DEP identify their macroinvertebrate samples to the family level). Identification of macroinvertebrates to the family is easier to perform and yields results that are suitable for our purposes. Another reason for choosing this level of identification was the interest of local watershed groups in performing macroinvertebrate sampling. For these groups genus level identification would be too difficult and time consuming. In order for the County to accept their data, however, the identifier would have to pass a quality assurance program established by the County.

The following are tables for the scoring schemes.

Pocono Plateau, Riffle / Run < 10 square miles

Samples from Keiper Run, Beaver Creek, Cross Keys Run, Frame Cabin Run and Tripup Run were used to develop the reference condition.

Reference Scoring System for the Pocono Plateau, Riffle / Run < 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 15	14 - 8	7 - 0
EPT Taxa	> = 8	7 - 4	3 - 0
HBI	< = 5.4	5.5 - 7.7	7.8 - 10
% Intolerant Taxa	> = 35.3	35.2 - 17.7	17.6 - 0
% Noninsect	< = 2.0	2.1 - 25.0	25.1 - 100
Shredders / Total	> = 0.02	0.019 - 0.01	0.009 - 0

The reference sites were all scored using this scoring scheme. The lower 25th percentile of the reference scores represents the lower threshold for the "optimal" category. The 25th percentile of the reference scores is 26. The range 25 - 16 represents the slightly to moderately impaired category, and any site with a total score of less than 16 will be considered severely impaired.

Pocono Plateau, Riffle / Run > 10 square miles

Samples collected at Tunkhannock Creek and Tobyhanna Creek were used to develop a reference condition for the larger streams on the plateau. Descriptive statistics for the metrics at these two sites were calculated and the resulting scoring scheme was developed as described previously. The scoring scheme for the larger streams is shown in the following table.

Reference Scoring System for Pocono Plateau, Riffle / Run > 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 15	14 - 8	7 - 0
EPT Taxa	> = 8	7 - 4	3 - 0
HBI	< = 5.7	5.8 - 7.9	8.0 - 10
% Intolerant Taxa	> = 39.3	39.2 - 19.7	19.6 - 0
% Noninsect	< = 3.6	3.7 - 25.0	25.1 - 100
Shredders / Total	> = 0.003	0.0029 - 0.0015	0.0014 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference scores is 26. The range 25 - 16 will be the slightly to moderately impaired category, and any site with a total score of less than 16 will be considered severely impaired.

Pocono Plateau, Glide / Pool

Samples collected at Tunkhannock Creek were used to develop a reference condition for the glide pool streams found in the Long Pond area. Descriptive statistics for the metrics at these sites were calculated and the resulting scoring scheme was developed as described previously. The scoring scheme for the glide pool streams is shown in the following table.

Reference Scoring System for the Pocono Plateau, Glide / Pool

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 15	14 - 8	7 - 0
EPT Taxa	> = 6	5 - 3	2 - 0
HBI	< = 5.5	5.6 - 7.8	7.9 - 10
% Intolerant Taxa	> = 26.7	26.6 - 13.4	13.3 - 0
% Noninsect	0	>0 - 25.0	25.1
Shredders / Total	> = 0.01	0.009 - 0.005	0.0049 - 0

The reference sites were all scored using this scoring scheme. The lower 25th percentile of the reference site scores represents the lower threshold for the "optimal" category. The 25th percentile of the reference scores is 28. The range 27 - 17 is the slightly to moderately impaired category, and any site with a total score of less than 17 will be considered severely impaired.

Low Pocono, Riffle Run, Riffle / Run < 10 square miles

Samples from Spruce Cabin Run and Buck Hill, Rattlesnake, Mill, Poplar Run, Devils Hole, Fall, Poplar and Swiftwater Creeks were used in developing a scoring scheme for this region. Descriptive statistics for the metrics at these sites were calculated, and the resulting scoring scheme was developed as described earlier. The main difference between the metrics from the Pocono Plateau and Low Pocono sub-ecoregions is the inclusion of the percent dominant family for the Low Pocono.

Reference Scoring System for the Low Pocono, Riffle / Run < 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 16	15 - 8	7 - 0
EPT Taxa	> = 11	10 - 6	5 - 0
HBI	< = 4.5	4.6 - 7.3	7.4 - 10
% Dominant Family	< = 42.6	42.7 - 71.3	71.4 - 100
% Intolerant Taxa	> = 55.6	55.5 - 27.8	27.7 - 0
% Noninsect	< = 0	0 - 25.0	25.1 - 100
Shredders / Total	> = 0.11	0.10 - 0.06	0.05 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference sites scores is 31. The range 30 - 19 will be the slightly to moderately impaired category, and any site with a total score less than 19 will be considered severely impaired.

Low Pocono, Riffle / Run > 10 square miles

Samples collected from the Bushkill, McMichaels, Brodhead, Paradise, and Pocono Creeks were calculated and the resulting scoring scheme was developed.

Reference Scoring System for the Low Pocono, Riffle / Run > 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 17	16 - 9	8 - 0
EPT Taxa	> = 10	9 - 5	4 - 0
HBI	< = 5.6	5.7 - 7.8	7.9 - 10
% Dominant Family	< = 46.3	46.4 - 73.2	73.3 - 100
% Intolerant Taxa	> = 35.7	35.6 - 17.9	17.8 - 0
% Noninsect	< = 9.6	9.7 - 25.0	25.1 - 100
Shredders / Total	> = 0.03	0.029 - 0.015	0.014 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference scores is 29. The range 28 - 18 will be the slightly to moderately impaired category, and any site with a total score of less than 18 will be considered severely impaired.

Northern Shale Valleys and Slopes, Riffle / Run < 10 square miles

Samples collected from the Princess, Ross Common, and Cherry Creeks were calculated and the resulting scoring scheme was developed. This scoring scheme follows the work that has been completed for the Low Pocono subecoregions in that it also includes the percent dominant family metric.

Reference Scoring System for Northern Shale Valleys and Slopes, Riffle / Run < 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 18	17 - 9	8 - 0
EPT Taxa	> = 9	8 - 4	3 - 0
HBI	< = 5.0	5.1 - 7.5	7.6 - 10
% Dominant Family	< = 34.9	35.0 - 71.4	71.5 - 100
% Intolerant Taxa	> = 26.1	26.2 - 13.0	12.9 - 0
% Noninsect	< = 5.6	5.7 - 25.0	25.1 - 100
Shredders / Total	> = 0.14	0.139 - 0.070	0.069 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference scores is 31. The range 30 - 18 will be the slightly to moderately impaired category, and any site with a total score of less than 18 will be considered severely impaired. It should be noted that only six sites were used in creating this scoring scheme. It will be adjusted after further studies have provided more data.

Northern Shale Valleys and Slopes, Riffle / Run > 10 square miles

Samples collected from the McMichaels, Pohopoco, Aquashicola, Cherry, and Buckwha Creeks were calculated and the resulting scoring scheme was developed.

Reference Scoring System for Northern Shale Valleys and Slopes, Riffle / Run > 10 square miles

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 19	18 - 10	9 - 0
EPT Taxa	> = 11	10 - 6	5 - 0
HBI	< = 5.1	5.2 - 7.6	7.7 - 10
% Dominant Family	< = 42.6	42.7 - 71.4	71.5 - 100
% Intolerant Taxa	> = 28.6	28.5 - 14.3	14.2 - 0
% Noninsect	< = 3.9	4.0 - 25.0	25.1 - 100
Shredders / Total	> = 0.02	0.019 - 0.009	0.008 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference scores is 31. The range 30 - 18 will be the slightly to moderately impaired category, and any site with a total score of less than 18 will be considered severely impaired.

Northern Sandstone Ridges, Riffle / Run

Samples collected from the Poplar, Caledonia and Ross Common Creeks were calculated and the resulting scoring scheme was developed.

Reference Scoring System for the Northern Sandstone Ridges, Riffle / Run

Score Assigned →→→→ Metric	5 (Optimal)	3 (slightly to moderately impaired)	1 (Severely impaired)
Total Taxa	> = 16	15 - 8	7 - 0
EPT Taxa	> = 10	9 - 5	4 - 0
HBI	< = 3.9	4.0 - 7.0	7.1 - 10
% Dominant Family	< = 24.1	24.2 - 62.1	62.2 - 100
% Intolerant Taxa	> = 37.5	37.4 - 18.8	18.7 - 0
% Noninsect	< = 2.2	2.3 - 51.2	51.3 - 100
Shredders / Total	> = 0.09	0.089 - 0.045	0.044 - 0

The reference sites were all scored using this scoring scheme. The 25th percentile of the reference scores is 33. The range 32 - 17 will be the slightly to moderately impaired category, and any site with a total score of less than 16 will be considered severely impaired.

PADEP Assessment Results

Ms. Sheree Wills of the Pennsylvania Department of Environmental Protection, Northeast Region, Wilkes-Barre, PA, completed assessments of streams in the Pocono Creek watershed during the summer of 1998. 24 stream segments were assessed for habitat and macroinvertebrates using the PADEP unassessed waters protocols (ref) and minimal water quality constituents (pH, hardness, and alkalinity).

Under PADEP criteria, only one of the 24 sites scored poorly enough to be classified as impaired, at Pocono Creek above Flagler Run. This site is impacted by storm water runoff from the Stroud Mall, where Flagler Run is completely encased within a culvert and blacktopped over. Only pollution-tolerant families were found here, and ecological function is disrupted. Imperviousness at the site is 100%, and storm water is channeled directly into this segment of stream.

Another site, Cranberry Creek just below Cranberry Bog, also scored as impaired though a special case exists here. Cranberry Creek in the vicinity of Cranberry Bog probably is functioning properly in the unique way an alpine bog functions. Ms. Wills found low pH in this stream with the characteristic “tannic tea” color found in other areas atop the Pocono Plateau, where swampy conditions and pine trees prevail. Insufficient substrate, habitat or nutrients exist to support the same macroinvertebrate community found in most portions of the watershed. Other low gradient, tannic acid streams exist in the headwaters of the Pocono Creek watershed. These streams probably should not be scored under the same criteria as a real “trout” stream.

Assessment personnel should consider using the MACS (Mid-Atlantic Coastal Streams Workgroup, 1998; Maxted 2000) system of assessing low-gradient streams. The MACS procedure was developed by biologists from U.S. EPA Region III, with state agencies from North Carolina, Virginia, Maryland, Delaware, and New Jersey. The low gradient protocol was developed specifically because they found so many streams that did not “fit” the macroinvertebrate and habitat models most commonly used in high-gradient, riffle-pool, gravel-cobble-boulder streams. Their streams are dominantly composed of sand or small gravel bottoms, and the best habitat is usually the woody debris common in these slower, meandering streams.

All habitat scores ranged within Optimal or high Sub-Optimal categories. This indicates that this stream is resilient to anthropogenic damage. Even with Route 80 running up one side and Route 611 up the other, and numerous crossings, thin riparian buffers, and fairly extensive channel modifications, the habitat for macroinvertebrates remains nearly optimal. Evidence suggests that it takes an extreme case of habitat degradation along with direct storm water inputs to cause the stream to be impaired under PA criteria.

Are the Pocono Creek streams that good? Or are state criteria too “loose”? Probably the answer is a little of both. Pocono Creek is composed of substrate that is not easily eroded, and that provides excellent substrate quality of habitat for stream life. When stream instability occurs, it heals quickly in many places (see section discussing stream channel stability). However favorable the environment, some severe degradation has occurred locally. The technical committee has agreed that existing state criteria allow for considerable degradation to high quality waters such as the Pocono Creek, and such a case is unacceptable for protection of this stream. State criteria are based upon an average condition of streams statewide, and Pocono Creek far exceeds such average conditions. Very fortunately for protection of this watershed, a biological monitoring system sensitive enough for high-quality criteria development has been developed locally by Monroe County, with assistance of the U.S. Environmental Protection Agency, Region III (Passmore and Green, 1997).

How high must we “set the bar” (minimum water quality standards) so that no degradation occurs? “Impairment” is a relative term. What scores as non-impaired for the state 303d list may look pretty impaired to regional biologists used to seeing high-quality or exceptional value streams. How high should our minimum standards be, considering the balance between stream protection and economic growth of Monroe County? How high would standards have to be before they are considered as economically burdensome?

The technical committee agreed to use Monroe County’s biological monitoring program and reference metrics calculated for the area as the “bar” that protection of the resource must reach. Monroe County’s biological monitoring criteria are more stringent than the state of Pennsylvania’s, and are adapted locally and directly applicable to the ecoregions encompassing the area. As management alternatives are developed and implemented, the local scoring system will be used to measure the overall success or failure of future protection and restoration efforts.

Simply stated, Pocono Creek's existing conditions are biologically optimal or sub-optimal. Targets have been established in each of this study's six management areas, based upon the Monroe County reference scoring schemes. Table ___ shows results of all samples taken from the Pocono watershed to date.

Management Area	Existing Conditions 1998-2000 (# of Sites)	Target
1	Slightly Impaired (3) – Moderately Impaired (1)	Slightly Impaired – Optimal
2	Slightly Impaired (1) – Optimal (1)	Slightly Impaired – Optimal
3	Slightly Impaired (3) – Optimal (2)	Optimal
4		Optimal
5	Optimal (4)	Optimal
6	Moderately Impaired (1) – Slightly Impaired (1) – Optimal (1)	Optimal

Table ___: Monroe County Macroinvertebrate Scoring System, 1998-2000 Results. These data were used to define existing conditions for the Pocono Creek watershed, and represent the target scores necessary to satisfy protective and restorative measures taken in future years.

Fish

Even though Monroe County has developed a robust, predictive, and elegant biological monitoring system through use of the benthic macroinvertebrate assemblage, no monitoring or assessment is complete until fish are included an analysis of water quality. Fish represent the top of the food chain, historical data are extensive, and all use classifications pertaining to state waters are based upon water quality requirements for fish. As stated previously, the Pocono Creek watershed contains streams were classified by the state as high quality coldwater fisheries, exceptional value streams, and Class A wild trout streams.

Pocono Creek was surveyed by fish electroshocking techniques in 1998 and 1999, and historical data has been provided by the Pennsylvania Fish and Boat Commission, dating back to the 1980's. Biomass of brown trout and brook trout is of sufficient quantity to maintain Pocono Creek in its status as a Class A wild trout fishery.

The 1999 survey results reported by David Arnold, PAFBC, show that the Class A status was threatened by that summer's severe drought. The drought conditions reduced stream flows and suitable habitat to such an extent that abundance and biomass of wild brown trout were reduced by over 60% (from 1998 levels) in the lower sections of Pocono Creek. Recommendations included installation of habitat improvements, specifically low flow deflectors, and adjustments to stocking allocations. Mention was made in the report of habitat loss due to construction of channels and dikes after the 1955 flood. According to the report, the PAFBC plans to re-survey the Pocono Creek in 2002.

Brown trout were chosen as a target species used to fulfill goals established for protection of stream flow in the Pocono Creek watershed. A model developed by the Pennsylvania Fish and Boat Commission (Leroy Young trout model REF) predicts trout habitat loss associated with reduction of stream flow. See the Flow Needs section of this report for further discussion of flow reduction versus trout habitat loss. We recommend that the trout habitat model be calibrated to the Pocono Creek watershed prior to its use in assessment of stream flow conditions related to management decisions. We also recommend that additional and frequent fisheries surveys be conducted so that baseline conditions can be established for reference conditions. Fish have been successfully used to document impacts or improvements to water quality, erosion and sediment, channel stability, and flow. Further collection and analysis of the fish assemblage is necessary for full use of biological criteria in protection and restoration of the Pocono watershed.

Why Worry About Naturally Stable Channels?

- ♥ Less Restoration and Maintenance Costs
- ♥ Preserves Water Quality & Aquatic Life
- ♥ Preserves In-Stream Habitat
- ♥ Preserves Recreation Quality & Aesthetics
- ♥ Preserves Property

Rosgen Level I Analysis of Stream Channel Stability - Introduction

For our analysis of existing channel stability conditions in the Pocono Creek watershed, we employed the first level of a four-level natural channel design and restoration methodology devised by David Rosgen, Professional Hydrologist, of Wildland Hydrology, Pagosa Springs, Colorado. The Rosgen method uses measurable properties of naturally stable stream channels, including geometry, patterns, longitudinal profiles, bed materials, and erosional and depositional processes to determine the extent of instability of impacted streams and, if necessary, restore a stream channel to its natural state of equilibrium.

The Rosgen stream classification system (Rosgen 1994; See Figure __) was applied to all streams in the Pocono Creek watershed to:

- Define existing stream channel stability conditions;
- Provide a management framework to prioritize preservation or restoration options; and
- Quantify targets used to meet goals desired by residents of Monroe County, PA.

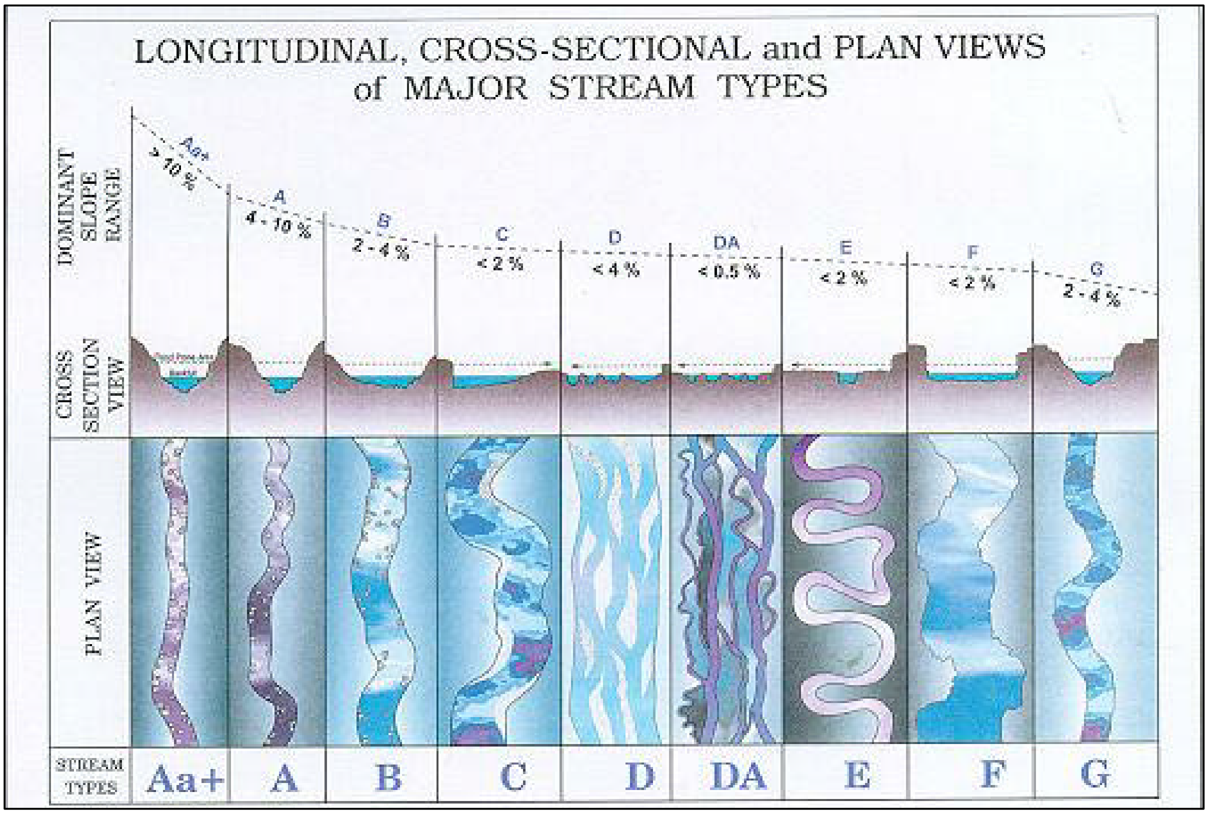

Figure ___: Stream Classification System by Rosgen (1994). All Pocono Watershed streams were classified visually (Level I) in December 2000.

Publicly stated goals addressed by this assessment included:

- Preservation of stream corridors and floodplains;
- Reduction of stream bank erosion and sedimentation; and
- Preservation of open space.

Many variables influence stream stability, including streamflow, width, velocity, depth, slope, roughness of channel materials, sediment volumes, and sediment sizes. A stable stream maintains a minimum energy expenditure balance dictated by these inter-related variables, known as its most probable state (Leopold, 1994). In its most probable state, a stream can carry the sediment load supplied by the watershed without changing its dimension (cross sectional area, width, depth, shape), pattern (sinuosity, meander pattern), or profile (longitudinal pattern and slope), and without aggrading (building up of bottom materials) or degrading (cutting down into the landscape and abandoning the natural floodplain). This state is also referred to as equilibrium (see Figure __, from Rosgen, 1996: Lane, E.W., 1955. The importance of fluvial morphology in hydraulic engineering. ASCE Proceedings 81, paper 745: 1-17).

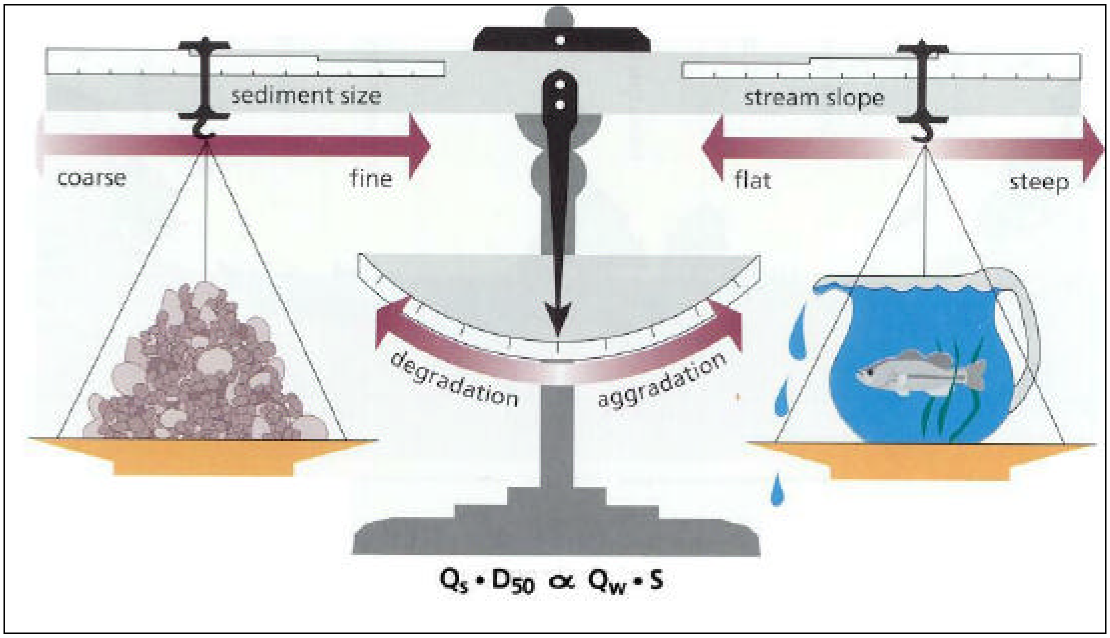

Figure ___. Factors affecting channel degradation and aggradation.
Size and total quantity of sediment particles moved by the stream are balanced by the stream's energy, slope, and water flow. These together determine the size of a stream channel. If one variable is changed, or natural dimensions are changed, the stream must adjust to reach equilibrium. Source: Rosgen (1996) from Lane (1955).

Most of the work done by a stream in creating and maintaining its natural channel occurs during storms at a frequency of approximately every 1.5 years (Wolman, M.G., and Miller, J.P. 1960. Magnitude and frequency of forces in geomorphic processes. Journal of Geology 68: 54-74). These are "bankfull" floods, where water levels reach the incipient point of spilling over onto the floodplain. Wolman and Miller (1960) determined that the majority of a stream's sediment load is carried by the bankfull storm event. All dimensions measured to determine the state of channel stability are thus related to the bankfull stage.

A radical change to any of the above variables can cause a stream channel to become unstable, while adjusting its dimensions and patterns back toward a state of equilibrium. While a stream is in the process of making an adjustment to disturbance, instream habitat is lost and ecological function is reduced, as measured by decreased diversity, richness, balance, and pollution intolerance of aquatic life. (Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7, Bethesda, MD). Unstable stream channels produce excess sediment, and cause localized problems downstream in the form of sediment deposition (aggradation, which smothers habitat) or scouring and incision (degradation, where rocks move that normally would not). Both aggradation and degradation are processes that interrupt the stream bed's substrate stability necessary for completion of aquatic life cycles. Unstable streams will heal, or re-achieve equilibrium in time. When that stream does heal, however, it is unlikely that the pre-existing aquatic biological communities will return just as before the disturbance.

The first option to consider in stream restoration is to leave the stream alone, and let it heal on its own. We must decide whether we have the time to wait for the channel to adjust, because during that time we experience more direct economic effects such as: property loss, increased magnitude, frequency and duration of floods and droughts, reduced water quality, reduced fisheries, reduced aesthetics, and reduced property values. Sometimes a sort of domino effect of instability occurs from one small act, causing an entire watershed to sort of "unravel." In those cases, the stream may heal in one area while adjustments are transferred in an upstream or downstream direction, and those adjustments may take several of our lifetimes to complete. In those cases, intervention is certainly required.

For example, if we mine a stream for its gravel, we change the local slope of the stream. Imagine a small waterfall at the hole where there used to be a flat run of stream. Waterfalls possess high erosive energy. As the stream re-adjusts to match the slope of the surrounding valley (its most probable state), that waterfall must somehow be flattened out to lessen the local slope. While that occurs, erosion of the stream bottom takes place, and that erosion is known as a headward cut, or "head cut." Head cuts are incisions or forms of channel degradation that migrate upstream for potentially very great distances, until the slope created by that gravel mining activity hits a natural hard point such as a rock outcrop or bedrock, or until the slope of the head cut matches the valley slope. That part of the natural stream could be miles from the original area of stream channel that was mined. The simple act of mining gravel from a streambed can produce many tons of excess sediment that all gets deposited downstream. The situation just described is very common in Pennsylvania's agricultural watersheds. This was also reported in areas of the Catskills in New York State that are very similar in geologic structure to the Pocono watershed (Jock Conyngham, Trout Unlimited, presented at the Delaware River Basin Monitoring Congress, Delaware Valley College, 1999).

Another example that is readily apparent to anyone visiting the Pocono watershed is road and bridge construction. The Pocono watershed is bisected by two major highways, Interstate 80 and PA Route 611. A great quantity of concrete and numerous stream crossings were required to complete those projects. In doing so, smooth concrete channels were created, and natural channel meanders were straightened to accommodate the roads. In both cases, the stream channel had to adjust to increases in velocity and decreases in channel roughness upon removal of streambed, bank substrate, and meanders. Roughness from bed and bank materials, and redirection of flow and reduction of flood energy provided by meanders had kept the power of the stream in check and in equilibrium when floods occurred. We believe that channeling the stream created fairly severe damage downstream, at least for a short period of time. Floodwaters now moved faster and straighter, directing flow and additional erosive power downstream to channels naturally formed to accommodate much less velocity and flow. Adjustments downstream were observed during our survey, including: channel widening; formation of multiple channels; bank erosion; down-cutting (incision); abandonment of floodplains; and further transfer of energy and sediment supply downstream. Further downstream, in slower and more gently-sloped reaches, much of the excess sediment produced had dropped out of suspension during floods, raising the bed of the stream and flooding areas of Stroudsburg that had never before flooded.

Any activity by man on a natural stream channel can change one of those eight variables dictating channel stability. In the Pocono watershed, we directly observed stream channel aggradation and degradation resulting from a number of causes, such as (in no particular order): stream crossings (bridges and culverts); dams; straightened meanders (channelization); bank and channel stabilization projects; storm water pipes; road gullies; debris; draining of wetlands; flood control measures; impervious surfaces; mowing of streamside vegetation; introduction of invasive/exotic plants; and encroachment into flood plains. Which disturbances or impacts are the most severe? How can we tell natural from anthropogenic sources of excess sediment? Which disturbed streams can we allow to naturally heal without any intervention? What measures give us the most "bang for our buck" in keeping such a high quality stream in a naturally stable state? We need a logical, inexpensive, and replicable process to determine where we stand, where we need to go, and how much it is going to cost to get where we desire.

In setting our primary target, we employ here a process of evaluation that will lead to maintenance of naturally stable channels, and achieving stability in problem-causing areas. Our challenge is to hit our target while maintaining the high environmental quality of life that most residents of the Pocono Creek watershed now experience.

The Rosgen Level I Assessment Process - Procedure:

Visual Assessment and Prediction of Stream Types (Rosgen Level I Survey). From GIS, topographic maps, photographs, and direct observation, predict Rosgen stream types (APPENDIX __ lists all streams, and classifies all stream segments) for all waterways within the Pocono watershed. This step was completed in December 2000. Robert Limbeck and Matthew Hoyt of DRBC either drove or hiked all 92 miles of streams in the watershed, and delineated observed stream types on 1:24,000 USGS topographic maps and county road maps. All stream crossings were evaluated visually for signs of channel instability. Additional prediction and visual verification was performed using digital elevation models, aerial photographs, and digital photographs. A database was created of all stream segments (MS EXCEL file) and mapped in Arc Info GIS (ESRI).

Areal Delineation. We quantified relative percentages of stream types in the entire Pocono watershed, and in each management area. We determined the amount and percentage of unstable channels observed in each management area (see Figure __ for results). Karen Reavy of DRBC mapped segments in Arc Info GIS system.

STREAM TYPES OF THE POCONO WATERSHED
MANAGEMENT AREA PERCENTAGES

Assign Morphological Values (with caution!). Assemble delineative criteria and general stream stability properties from Rosgen (1996), Table 4-1 and Figures 4-2, 4-4, and 5-2. Note for each stream type observed in the Pocono watershed the quantitative ranges of factors controlling the pattern, dimension, and profile. These include the slope, sinuosity, width/depth ratio, entrenchment ratio, dominant bed material sizes, meander patterns, and beltwidth (degree of confinement of stream). These literature values, derived from field verified empirical data, are used to note the most critical properties determining the stability of Pocono streams. Literature values should be used with caution, and further study is necessary to verify quantitative ranges of controlling factors, especially before those numerical values are applied to engineering and restoration designs. In successive studies, further analysis should be conducted using Rosgen Levels II, III, and IV protocols. We must quantify actual morphological values rather than blindly accept literature values.

POCONO STREAM TYPES – MORPHOLOGICAL CRITERIA

Develop Management Alternatives. Use Table 8-1 (Rosgen, 1996) to determine management alternatives. Certain stream types are more susceptible to physical disturbance, recover more easily from disturbance, possess higher sediment supplies, possess more erosive banks, and are controlled more by vegetation. These properties, once identified, can lead to identification of areas requiring more or less protection. Each of these properties might be the single most important determinant of channel stability for that stream type.

Rosgen's system must be used with caution, and stresses data gathering. Level I analysis is only a prediction of stream types based upon visual observation. It is fairly accurate when used to classify streams. Level I was calculated by discriminant analysis to be 92.5% accurate in correct identification of Rosgen stream types within a Wisconsin National Forest (Savery et al. 2001). Verification of stream types by Level II morphometry is necessary to classify streams near the edges of classification boundaries. Many Pocono stream types lie near those edges, such as stable C's forming within previously unstable F's; stable A, B, or E types incising into unstable G types. It is difficult, without field data collection, to identify some of the Pocono's A vs. B streams, or C vs. E streams, or F vs. G streams. Until a Level II analysis is completed in difficult-to-identify stream types, we can only safely conclude that a stream is C/E (low gradient stable), A/B (high gradient stable), or D/F/G (entrenched unstable).

Selection of local reference streams, and prioritization of impacted unstable streams for application of Levels II, III, and IV of the Rosgen restoration protocols is considered to be a Phase II activity of this project. Further resources must be sought to complete such an intensive data collection effort. Once the local partners decide which stream reaches must be restored instead of left to heal naturally, then this plan can serve as the basis for logical restoration efforts.

Channel Evolution Scenarios

When the stable stream types "go bad", that is, tend toward instability with an increased flow duration & magnitude, or an increased sediment supply, or when physically disturbed, they follow typical evolutionary scenarios that eventually lead back toward stability, but at a different elevation within the landscape. See Figure ___, showing various stream type evolution scenarios. This is useful in designing appropriate channel configurations in restoration, and assessing whether a study reach has reached its most probable stable form. For example, E channels typically evolve toward G channels when they become unstable in the presence of disturbance. Interpreting this shift using the morphological values taken from the literature, field measurements would show an increase in stream slope, a marked decrease in the entrenchment ratio (the floodplain is abandoned as the stream cuts into the landscape), and probably a decrease in sinuosity and in the meander width ratio (belt width/bankfull width). Annual monitoring of representative stream reaches and cross-sections would indicate evolution of a stream channel from a stable form (within reference tolerance ranges), toward instability (morphological values tending toward outer limits of tolerance ranges, with observed channel adjustments).

Interpret Morphology, Present Management Alternatives

Examples follow. The C3 stream type is commonly observed in the lower Pocono Creek. According to Table 8.1 (Rosgen, 1996, shown as Figure ___), a C3 stream is moderately sensitive to disturbance, can recover naturally if the disturbance is removed, provides a moderate sediment supply to the stream system, banks are moderately erodible, and vegetation is very important to stream stability. When a C3 goes unstable, it can do so in two directions: by over-widening, eroding stream banks, creating mid-channel depositional bars - that is - turn into an aggraded D channel, or by cutting down into the landscape (gullying), and abandoning the floodplain (a degraded G channel). A C3 stream is thus quite sensitive to disturbance by human alteration. To protect a C3 stream, aggradation and degradation must be prevented, and the stream must be allowed to keep its floodplain, slope, and meander pattern so that sediment can be transported. Recommendations to management would include:

- Protect the floodplain, do not build.
- Do not mine point bars.
- Do not straighten the stream - meanders reduce erosive power.
- Bridge culverts should not be too wide or narrow (maintain the stream's width to depth ratio at bankfull flood stage), and should include floodplain openings for overbank flows.
- A vegetated riparian buffer is very important to maintain bank stability and water quality. Removal of the buffer will cause stream instability at the removal site and downstream.

In contrast, a B3 stream is more "bomb-proof", or insensitive to human disturbance. Also commonly found in higher slope streams of the Pocono watershed, it takes a lot of change in flow duration and magnitude, and sediment increases, to cause a B3 to tend toward instability. If a disturbance is removed, a B3 should recover well on its own according to Rosgen’s list of management alternatives. B3 channels inherently possess low sediment supplies, because it is hard to erode the banks, and vegetation is not as important for bank stability as with a C3 channel. As seen often along Pocono Creek, you can build close to the stream without harming stability.

B3 channels don't require as much floodplain as C3 channels. B channels are typical of Pennsylvania trout streams, with frequent riffles, and higher slope and velocity than C channels.

The last stable form most typical of the Pocono Creek watershed is the E channel (substrate size unknown at this time). Some E3 channels may exist, but such coarse cobble bed material is unlikely. E channels are found in very low gradient areas, like the swamps on top of the Plateau. E channels are narrow, deep, highly meandering, with a wide floodplain, and very well vegetated banks. Any disturbance to these features will turn a stable E channel toward unstable C or G channels. Vegetation is critical to maintenance of bank stability, and once the vegetation is removed, the banks can severely erode. E channels are nature's most efficient way of moving high sediment supplies through low-gradient landscapes, and possess excellent habitat for fish. Fish love the deep, narrow channels with overhanging vegetation.

Other channel types observed in the Pocono Creek watershed include A and Aa+ channels (steep slopes), which are naturally erosive but stable channels. The unstable channels observed in the Pocono watershed are the common "problem" channels - D, F, and G. These indicate either over-widening, with associated bank erosion and in-channel deposition (aggradation) or gullying (degradation). Both processes produce a lot of sediment, possess terrible habitat and water quality values, and are unstable, transitional channel forms. These will evolve back to stable B, C, and E channels either naturally (in absence of further disturbance) or through restoration efforts. Table 8-1 (Rosgen 1996) lists natural recovery potentials of stream types, useful for setting restoration priorities. First priority should be non-intervention, if possible.

PADEP Bioassessment Results (1998)

980707-1130
Pocono Creek – Second riffle upstream of confluence with McMichaels Creek
Borders SR 611 corridor into Stroudsburg, area of commercial use, passes under Main Street (209). Narrow riparian strip. pH 7. Land Use 50 Res, 30 Comm, 20 Forest.
Rating: Not Impaired.
Habitat Assessment Score = 181 = 75%. (Optimal/Sub-Optimal)
Macroinvertebrates: EPTs abundant, sample looks good. 15/16 categories scored well.

980707-1400
<u>McMichaels Creek – 100 yds upstream of Rt 80 bridge</u>
Site borders Katz Recycling Center and formerly a junkyard. Labar Village is a seniors community with living quarters, apartments, restaurant. This area was formerly a rhododendron nursery, is landscaped with ponds and lawns.
pH was 7.5. Land Use 40 Res, 20 Comm, 10 Indus, 30 Forest.
Rating: Not Impaired.
Habitat Assessment Total Score = 175 = 73%. (Sub-Optimal/Optimal). Some embeddedness.
Among habitat categories, this site received a marginal score for sediment deposition.
Macroinvertebrates: EPTs abundant, many intolerant taxa, 14/16 categories scored well.

980707-1000
<u>McMichaels Creek – First riffle downstream of Pocono Creek confluence</u>
Route 80 along SE shoreline, wooded along other bank. Downstream of Stroudsburg and West Main Street.
pH was 7.0. Land Use: 50 Res, 30 Commercial, 20 Forest.
Rating: Not Impaired.
Habitat Assessment Total Score = 174 = 73%. (Sub-Optimal/Optimal).
Macroinvertebrates: EPTs abundant, intolerant taxa prevalent, 15/16 categories scored well.

980211-0900
Pocono Creek – 10 yards upstream of Flagler Run confluence.
Notes: Downstream of SR611 and Stroud Mall. Strip malls upstream. Receives stormwater from malls, highway, and parking lots.
Land Use: 5 Residential, 85 Commercial, 10 Forest.
Assessment Rating: Impaired Biology.
Habitat Assessment Total Score = 161 = 67% (Sub-Optimal). Problems = Marginal rating received for disruptive pressure to stream, and marginal riparian vegetation.
Macroinvertebrates: Good scores for only 6 of 16 categories.
Problems included: Low abundance, low taxa richness, presence of only pollution-tolerant taxa. Only chironomidae were common.

980211-1015
<u>Flagler Run – Upstream of Old Mill Run Road (Upper creek, above mall)</u>
Notes: none.
Land Use: 40 Residential, 60 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 187 = 78% (Optimal). No habitat problems recorded.
Macroinvertebrates: Scored high in 15/16 categories. EPTs well-represented, pollution intolerant taxa present and abundant, high richness.

980611-1030

Big Meadow Run – at Mazzetti Road.

Notes: Forested residential area, christmas tree farm, wetlands, stream flows through swampy area. Not much gradient, so habitat scores lower w/o riffle areas, and with mucky substrate. Homes no closer than 500 ft at this site, no development downstream for about ½ mile. Stream passes through small impoundment before passing under 611 to mouth. Probably should use score sheet for low gradient streams at this site.

pH 6.5, Land Use: 35 Residential, 60 Forest, 5 Other (wetlands? impoundment?)

Assessment Rating: Unimpaired.

Habitat Assessment Total Score = 150 = 63% = Sub-Optimal. Received marginal habitat ratings for instream cover, frequency of riffles, condition of banks, bank vegetation. Low rating could be attributed to use of high-gradient habitat form for a low-gradient stream.

Macroinvertebrates: scored well in 13 of 16 categories. EPTs well-represented, though none were abundant.

980611-1230

Little Pocono Creek – near Pocono Creek confluence.

Notes: Samples taken 50 ft upstream of mouth. Behind Stroudsburg High School football field.

pH 7.5. Land Use: 60 Residential, 40 Commercial.

Assessment Rating: Unimpaired.

Habitat Assessment Total Score = 181 = 75% (Optimal/Sub-Optimal). No poor scores.

Macroinvertebrates: Good scores for 15 of 16 categories. EPTs well represented in pollution intolerant forms, blackflies very abundant.

980709-1000

Little Pocono Creek – Headwater portion by trailer park (dry above dirt road)

Notes: Site immediately downstream of 2 pipes under dirt road, small impoundment upstream, and dry above that point. Mostly agricultural use at site, upstream is wooded area with private residential use and 6-8 unit trailer park. Streams shown on map are dry above trailer park. Bug community influenced by upstream pond and small stream size (2' wide, 6-8" deep or less), lack of good riffles due to low gradient.

pH 7.5. Land Use: 30 Residential, 20 Crops, 35 Fields, 15 Forest.

Assessment Rating: Unimpaired.

Habitat Assessment Total Score = 157 = 65% (Sub-Optimal). Marginal scores for velocity/depth regime, grazing & disruptive pressure, and riparian vegetation.

Macroinvertebrates: Good scores for 12 of 16 categories. No stoneflies present. EPTs scored poorly. Too few pollution-intolerant taxa. Red chironomids were huge.

980709-1130

Little Pocono Creek – Downstream of Tanite Road bridge.

Notes: Samples taken from 2nd and 3rd riffles downstream of Tanite Road bridge. Residential development upstream has increased in last 5-10 years. Sewer line completed a few years ago.

pH 7.0. Land Use 50 Residential, 50 Forested.

Assessment Rating: Unimpaired.

Habitat Assessment Total Score = 173 = 72% (Sub-Optimal/Optimal). No marginal or poor scores.

Macroinvertebrates: Good scores for 12/16 categories. No stoneflies, EPTs scored poorly. Too few pollution-intolerant taxa. Hydropsychid caddisflies very abundant.

980709-1445
Wigwam Run – near confluence with Pocono Creek
Notes: Sampled 30 ft above Pocono confluence, below bridge. Stream comes out of ground 20 ft upstream of riffle, and 50 ft from confluence, where old railroad track was built. Another sample taken upstream of old railroad bed. Area forested, Rt 80 passes over creek upstream of railroad bed. Physical impairment due to runoff from 80 entering above Beech St, also along Schaefer Schoolhouse Road (30 ft), following bottom of hill east for about 100 yards, where stream goes underground, emerging other side of ridge about 50 feet above confluence with Pocono Creek. Biological samples taken above and below underground portion.
pH 6.0. Land Use: 30 Residential, 10 Commercial, 60 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 181 = 75% (Optimal/Sub-Optimal). No poor scores.
Macroinvertebrates: Good scores for 13 of 16 categories. EPTs represented in pollution intolerant forms, though not abundant. Only hydropsychid caddisflies listed as abundant.

980721-1030
Pocono Creek – downstream of confluence with Cranberry Creek
Notes: Sampled downstream of mouth of Cranberry Creek.
pH 6.5. Land Use: 25 Residential, 25 Commercial, 10 Fields, 40 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 188 = 78% (Optimal). No poor scores.
Macroinvertebrates: Good scores for 16 of 16 categories. EPTs represented in pollution intolerant forms, though not abundant. Sample dominated by Philopotamid caddisflies (pollution-intolerant).

980624-1000
Rocky Run – forested site – Intersection Reeders Run & Golden Slipper Rd.
Notes: Upstream is forested land, across road downstream is small lake and camp.
pH 5.0. Land Use: 100 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 186 = 78% (Optimal). No poor scores.
Macroinvertebrates: Good scores for 15 of 16 categories. EPTs represented in pollution intolerant forms.

980624-1100
Rocky Run – forested site – Opposite Int. Reeders Run & Golden Slipper Rd., SR 3028 Marker.
Notes: forested land, state gamelands, private camps. First kick in less-rapid riffle with sandy bottom and lots of wood debris. 2nd kick faster but still sandy bottom, lots of moss on rocks, with watercress, tannic water is orange-brown.
pH 5.5. Land Use: 100 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 175 = 73% (Sub-Optimal). No poor scores, substrate not as good as 1000.
Macroinvertebrates: Good scores for 15 of 16 categories. EPTs well-represented, but sample dominated by hydropsychid caddisflies.

980624-1220
Reeders Run – Near Intersection Reeders Run Rd & Gardner Rd.
Notes: Homes on either side, large lots with trees. Buffer strip on right is 20-30 ft wide.
Land Use: 50 Residential, 50 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 191 = 80% (Optimal). No poor scores.
Macroinvertebrates: Good scores for 15 of 16 categories. EPTs well-represented, but extremely pollution-intolerant taxa not well-represented.

980716-1040
Pocono Creek – above Stadden Road, below Bulgers Run.
Notes: Downstream of Tannersville along Learn Road. Downstream of commercial and residential area. Rocks covered with periphyton, some green algae.
pH 6.5. Land Use 30 Residential, 30 Commercial, 5 Crop, 5 Pasture, 30 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 190 = 79%. (Optimal). No poor or marginal scores.
Macroinvertebrates: EPTs abundant. 14/16 categories scored well. Sample dominated by Baetid mayflies, though many extremely pollution-intolerant taxa represented.

980723-0920
Cranberry Creek – at Route 611.
Notes: Sampled at 611 bridge north of Bartonsville PO, behind Pocono Peddlars Village. Small mall parking lot on north bank, commercial use along 611. Upstream watershed is mainly forested with some residential development.
pH 5.5. Land Use 15 Residential, 35 Commercial, 5 Fields, 45 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 179 = 75%. (Optimal/Suboptimal). No poor or marginal scores.
Macroinvertebrates: EPTs abundant. 16/16 categories scored well. Sample dominated by Leuctridae stoneflies (Hilsenhoff is 0).

980723-1120
Cranberry Creek – below Cranberry Bog. (UNIQUE? COMPARE TO OTHER SITES?)
Notes: Upstream is the preserve surrounded by some residential development. Bog conditions present a lack of suitable habitat to sample at this location.
pH 5.0. Land Use 5 Residential, 95 Forest.
Assessment Rating: Impaired for less than ½ mile.
Habitat Assessment Total Score = 155 = 65%. (Suboptimal). Poor or marginal scores in instream cover, epifaunal substrate, flow velocity & depth regime, and frequency of riffles.
Macroinvertebrates: 7/16 categories scored well. Sites scores as impaired, but special condition exists – site is located downstream of southernmost alpine boreal bog in U.S. Sample dominated by Amphipods. No EPTs, no pollution-intolerant taxa.

980721-0920
Bulgers Run – location unknown – placed site just above Learn Rd (GUESS).
Notes: No location listed in DEP notes.
pH 6.0. Land Use 25 Residential, 75 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 164 = 68%. (Sub-Optimal). No poor or marginal scores, though some scores relatively low for riparian vegetation, channel flow, and frequency of riffles.
Macroinvertebrates: 15/16 categories scored well. Sample dominated by Psephenidae beetle larvae (water pennies). Mayflies and caddisflies not abundant, though EPTs represented.

980716-1200
Pocono Creek – at Route 715, Tannersville.
Notes: Site located behind Billy's Diner along 611 upstream of 715 in Tannersville. Small strip mall and parking lot along one bank, The Crossing shopping outlet (96 stores & associated parking lots) beyond other bank. Nominal forested area along stream, composed mostly of weeds.
pH 7.0. Land Use 90 Commercial, 10 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 184 = 77%. (Optimal). No poor or marginal scores, though streamside disruptive pressure and riparian vegetation scored in the low sub-optimal range.
Macroinvertebrates: 14/16 categories scored well. Sample dominated by Baetid mayflies (tolerant), though many extremely pollution-intolerant taxa represented.

980722-0945
Scot Run – Approx. 1000 ft. above mouth, East of Rt 611.
Notes: none
pH 6.5. Land Use 40 Residential, 20 Commercial, 40 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 184 = 77%. (Optimal). No poor or marginal scores.
Macroinvertebrates: 16/16 categories scored well. Sample dominated by Philopotamidae caddisflies (intolerant). EPTs well-represented. Sample rich and diverse.

980716-1320
Pocono Creek – Below Camelback STP, at downstream end of Camelback property.
Notes: Site borders end of Camelback property, condominiums across street. STP effluent upstream.
pH 6.0. Land Use 40 Residential, 30 Commercial, 30 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 178 = 74%. (Sub-Optimal/Optimal). No poor or marginal scores, though disruptive pressure and riparian vegetation scored at low end of suboptimal range.
Macroinvertebrates: 16/16 categories scored well. Sample dominated by Peltoperlidae stoneflies (intolerant). EPTs well-represented..

980625-1200
Pocono Creek – above bridge on dirt road by sharp turn in Camelback Rd.
Notes: Dirt road runs along stream for various distances upstream.
pH 5.5. Land Use 30 Residential, 70 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 189 = 79%. (Optimal). One marginal score (bank vegetation) and condition of banks at low suboptimal range.
Macroinvertebrates: 14/16 categories scored well. Negative score for condition of banks, and EPTs not abundantly represented by intolerant families. Intolerant taxa were found but not abundant.

980625-1030
Wolf Swamp Run – at mouth.
Notes: Site located 10 yards upstream of mouth. Forest of rhododendron, hemlock, oak, birch. Sphagnum moss on rocks, banks. Watershed located in State Game Lands 38.
pH 5.5. Land Use 100 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 215 = 90%. (Optimal+). Only sediment deposition and bank vegetation scored suboptimal.
Macroinvertebrates: 15/16 categories scored well. Negative score for Simuliidae abundant in sample.

980625-1520
Dry Sawmill Run @ Crescent Lake Road.
Notes: Back road leads into residential community with lakes. Yard area mowed on left upstream side. Wood chips piled along bank by bridge. Home up steep bank on right side with dog. Some tree cover keeps stream shaded in afternoon. Water very yellow-brown, rocks have orange cast.
Land Use 50 Residential, 50 Forest.
Assessment Rating: Unimpaired.
Habitat Assessment Total Score = 174 = 73%. (Sub-optimal/Optimal). Bank vegetation scored marginal, bank condition, disruptive pressure, and riparian vegetation scored suboptimal.
Macroinvertebrates: 11/16 categories scored well. Baetidae mayflies (tolerant) abundant in sample. EPTs not well represented by intolerant taxa. Negative score for condition of banks.